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Postural Orientation of the Trunk and Pelvis from the initial contact to the midstance phase of gait: A Comparative Analysis of Post-Stroke and Healthy Individuals

Raquel Marques Granja

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Postural Orientation of the Trunk and Pelvis from the initial contact to the midstance phase of gait: A Comparative Analysis of Post-Stroke and Healthy Individuals

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Resumo

Introdução: O tronco e a pélvis desempenham papéis cruciais na marcha, e as incapacidades pós-AVC limitam essa função. Estudar a orientação postural do tronco e da pélvis em indivíduos saudáveis e pós-AVC pode melhorar as estratégias de reabilitação. **Objetivo:** Analisar a orientação postural do tronco e da pélvis durante a fase de contato inicial até a fase média de apoio da marcha em indivíduos pós-AVC comparados com saudáveis, identificando assimetrias dentro de cada grupo. **Métodos:** Estudo transversal com 16 participantes. Foram utilizados o sistema de capturas Qualisys® e plataforma de forças. Para análise dos dados estatísticos foram utilizados os testes de Mann-Whitney, Fisher e Wilcoxon. **Resultados:** O grupo pós-AVC apresentou maior tilt anterior da pélvis no contato inicial do membro ipsilesional, aumento da amplitude de movimento da pélvis no apoio do membro contralesional e maior assimetria. Além disso, demonstrou maior assimetria no ângulo lombar no contato inicial e diferenças na amplitude de movimento entre os grupos. A distância entre T2 e T7 não apresentou diferenças significativas. **Conclusão:** Indivíduos do grupo pós-AVC exibem maior tilt anterior e amplitude de movimento da pélvis, bem como maior assimetria nos ângulos pélvicos e lombares, em comparação com indivíduos saudáveis.

Palavras-chave: Pós-AVC, Marcha, Pélvis, Tronco.

Abstract

Introduction: The trunk and pelvis play crucial roles in gait dynamics. Post-stroke disabilities often limit gait function. Studying their postural orientation in healthy and post-stroke individuals can enhance rehabilitation strategies. **Objective:** Examine the postural orientation of the trunk and pelvis in the sagittal plane during the initial contact to midstance phase of gait in post-stroke individuals compared to healthy individuals, identifying asymmetries within each group. **Methods:** A cross-sectional study with 16 participants. Kinematic data were gathered using a Qualisys® motion capture system and force platforms. Data analysis was performed with SPSS, using the Mann-Whitney, Fisher and Wilcoxon tests. **Results:** The post-stroke group showed higher anterior pelvic tilt at initial contact of the ipsilesional limb, increased pelvic range of motion when the contralesional limb was in support, and greater asymmetry. The stroke group demonstrated significantly greater lumbar asymmetry at initial contact and differences in range of motion between groups. The distance between T2 and T7 revealed no differences between groups. **Conclusion:** Post-stroke group individuals exhibit increased anterior pelvic tilt and pelvic motion range during gait compared to healthy individuals. They also show greater asymmetry in pelvic and lumbar angles.

Keywords: Post-Stroke, Gait, Pelvis, Trunk.

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List of abbreviations

ASIS: Anterior superior iliac spine

CIR: Center for Research in Rehabilitation

cm: Centimeters

CONTRA: Contralesional

CoP: Center of Pressure

DOM: Dominant

Fz: Vertical force component

g: Gram

GBD: Global Burden of Disease

Hz: Hertz

BMI: Body Mass Index

IPSI: Ipsilesional

Kg: Kilogram

L1: First lumbar vertebra

L5: Fifth lumbar vertebra

LIAS: Left anterior superior iliac spine

LIPS: Left posterior superior iliac spine

m: Meter

MCA: Middle Cerebral Artery

mm: Milimeters

MMSE: Mini–Mental State Examination

NDOM: Non Dominant

PSIS: Posterior superior iliac spine

RIAS: Right anterior superior iliac spine

RIPS: Right posterior superior iliac spine

SD: Standard Deviation

T2: Second thoracic vertebra

T7: Seventh thoracic vertebra

WSO: World Stroke Organization

Table Index

1. Introduction

Based on the latest data from the Global Burden of Disease (GBD) report for 2021 stroke remains the second-leading cause of death worldwide and the third-leading cause of death and disability combined (Feigin et al., 2022; Global Burden of Disease, 2021). The World Stroke Organization (WSO) further emphasizes that each year, more than 62% of all strokes happen to individuals below the age of 70, with over 16% occurring in people aged 15 to 49 years. After a stroke disability persists in more than 75% of people, limiting the ability to regain functional independence in the activities of daily living, such as walking and sit-to-stand (Adegoke, Olaniyi, & Akosile, 2012; Mukherjee, Koutakis, Siu, Fayad, & Stergiou, 2013; Tennant, Geddes, Fear, Hillman, & Chamberlain, 1997; Verheyden et al., 2011).The persistent disability can partially be explained by the interruption of structural and functional pathways in the brain (Lefebvre & Liew, 2017). For instance, the corticoreticulospinal tract, that encompasses the corticoreticular pathway and the reticulospinal tract, is involved in the control of the axial muscles and the proximal muscles of the extremities. Lesions in these tracts could result in gait dysfunction and changes in postural control (PC) (Guggisberg, Koch, Hummel, & Buetefisch, 2019; Jang & Lee, 2019; Lefebvre & Liew, 2017), often predominantly affecting the ipsilesional side due to the involvement of the pontine reticulospinal tract, which is primarily disposed ipsilaterally (Baker, 2011; Karatas, Çetin, Bayramoglu, & Dilek, 2004; A. Silva et al., 2013; Westlake & Nagarajan, 2011).

PC plays a vital role in adjusting the body's position in relation to its surroundings, serving two primary purposes: orientation and stability. Postural orientation involves the ability to maintain an adequate alignment between body segments, establish a vertical orientation to counteract gravity, and it also encompasses the ability to maintain an appropriate relationship with the surrounding environment. Postural stability refers to the ability to maintain control over the center of mass (COM) relative to the base of support (BOS), involving the coordinated use of sensorimotor strategies (Bente E. Bassøe Gjelsvik, 2016; Novitri Sumardi, 2021). These elements collectively contribute to the overall ability to sustain a suitable body position in relation to both internal body segments and the external environment (Bassøe Gjelsvik & Syre, 2016; Novitri Sumardi, 2021).

Brain damage resulting from stroke often induces bilateral changes in the postural orientation of the pelvis and trunk, impacting both the ipsilesional and contralesional sides (S Karthikbabu, Rao, Manikandan, Solomon, & Chakrapani, 2011; Suruliraj Karthikbabu, Chakrapani, Ganesan, & Ellajosyla, 2017; Van Criekinge et al., 2017). Literature documents that post-stroke individuals frequently display poor trunk control, exaggerated anterior pelvic tilt and heightened bilateral forward-tilted pelvis, alongside lateral pelvic tilt towards the more affected side during standing (Suruliraj Karthikbabu et al., 2017; Van Criekinge et al., 2017). These alterations in postural orientation can significantly affect an individual's functional abilities and overall performance in day-to-day tasks (Darwish, Ahmed, Ismail, & Khalifa, 2019). Consequently, following a stroke, daily activities become impaired, necessitating a focused analysis of specific core tasks crucial for understanding post-stroke movement (Moore et al., 2018). These tasks include sitting, transitioning from sitting to standing, maintaining standing posture, step up/down, engaging in reach, grasp, manipulation activities and walking (Quinn et al., 2021; L. M. Silva & Stergiou, 2020).

In the context of gait, both the trunk and the pelvis play critical roles; in particular, the trunk is of significant importance in controlling movements in the sagittal plane throughout the gait cycle (Darwish et al., 2019; Sanz-Mengibar, Altschuck, Sanchez-De-Muniain, Bauer, & Santonja-Medina, 2017; Van Criekinge et al., 2017). Similarly, the pelvis serves as a critical link between the trunk and the lower limbs, facilitating weight bearing and enabling efficient weight transfer during locomotion (Darwish et al., 2019; In, Jung, Kim, Jung, & Cho, 2021; Tamaya et al., 2020). These interdependent contributions of the trunk and pelvis are essential components to be considered in the comprehensive understanding of gait dynamics and functional movement (Darwish et al., 2019; In et al., 2021; Sanz-Mengibar et al., 2017; Van Criekinge et al., 2017). Furthermore, the foot-floor contact of each lower limb plays a pivotal role in influencing the orientation and movement of the pelvis and trunk during gait. When the foot contacts the floor, it directly affects the force transmission through the lower limbs to the pelvis and trunk. Any alterations to this contact, as well as changes in the lower limb that is not in contact with the floor, could result in compensatory movements, which in turn could lead to varying behaviors of the trunk and pelvis, depending on which limb is in contact with the floor (Little, McGuirk, Perry, & Patten, 2018; L. M. Silva & Stergiou, 2020).

Understanding the postural orientation of the trunk and pelvis in both healthy and post-stroke individuals can lead to the development of more effective rehabilitation strategies for improving functional outcomes in post-stroke individuals, as the increasing incidence and current high survival rates of individuals who have suffered from stroke results in a substantial population of patients with neurological deficits that limit locomotor ability and postural control (Hornby, T. George, E. Henderson, Christopher Plawecki et al., 2019).

The primary objective of this study is to examine the postural orientation of the trunk and pelvis in the sagittal plane when the ipsilesional lower limb of post-stroke individuals is in the initial contact to midstance phase of the gait cycle, and when the contralesional lower limb is in the same phase. This will be compared to the postural orientation observed when the dominant and non-dominant lower limbs of healthy individuals are in the same phase. Furthermore, the study aims to identify any asymmetries or differences within the post-stroke group and within the healthy group when each limb is in support. By examining the postural orientation of these segments in the sagittal plane, this research aims to contribute to a more comprehensive understanding of post-stroke postural control and provide valuable insights for developing effective rehabilitation aimed at optimising and maximising functional recovery in individuals post-stroke.

2. Methods

2.1 Study design

This is a cross-sectional analytical observational study, in healthy and pathological individuals.

2.2 Sample

The research study comprises two distinct groups: healthy group consists of individuals who have not suffered stroke, while the post-stroke group encompasses individuals who have suffered from stroke, resulting in a total of 16 participants.

Individuals in the post-stroke group, comprising 1 female and 7 male, were recruited from the population of users of a Physiotherapy Clinic located in the Greater Porto region. The inclusion criteria for individuals who had experienced a stroke were as follows: a history of first-ever ischemic stroke involving the middle cerebral artery (MCA) territory, according to (Miller & Verstraete, 1999); independent ability to perform more than six sit-to-stand movements from a standard chair; capability to walk a distance of 10 meters with close supervision, if necessary, but without physical assistance, as assessed by the treating physiotherapist (Brunt, Liu, Trimble, Bauer, & Short, 1999); and provision of written or verbal informed consent (Elble, Moody, Leffler, & Sinha, 1994).

There were excluded from the study from the post stroke eligible participants all those who: have cognitive deficit that could hinder communication and cooperation (assessed by the Mini-Mental State Examination) (Bertolucci, Brucki, Campacci, & Juliano, 1994); have history of orthopedic or neurologic disorders (other than stroke) known to affect walking performance (Brenière, Cuong Do, & Bouisset, 1987); have history of stroke involving the brainstem or cerebellar areas (Brunt et al., 1999); and those who are taking medication that could affect motor performance (Brunt, Vander Linden, & Behrman, 1995).

To assemble healthy individuals (1 female and 7 male) were recruited using a network of personal acquaintances, including family and friends. The selection criteria aimed to ensure an anthropometric match with the participants from the post-stroke group, who resided in the Porto district.

In the healthy group were excluded if they were not born at term (i.e., during or after 37 weeks of gestation) due to the potential impact on postural control (Hadders-Algra, 2013). Furthermore, individuals with a history or current presence of orthopedic or neurological dysfunctions that could affect their ability to walk or stand up from a chair were also excluded. Participants with uncontrolled cardiac injury or pathology, thrombophlebitis, or those using medications known to impact motor capacity were excluded from the study. Additionally, individuals who had undergone surgery within the last six months or had implants or prostheses were excluded from the sample (Burnett, Campbell-Kyureghyan, Cerrito, & Quesada, 2011; Rowe, Beauchamp, & Astephen Wilson, 2021; A. Silva et al., 2015; Sousa, Santos, Oliveira, Carvalho, & Tavares, 2012).

2.3 Ethics

The study received ethical approval from the Ethics Committee of the School of Health at the Polytechnic Institute of Porto, under the reference number CE0054D (Attachment I). The research falls within the scope of Physiotherapy and aligns with the ongoing investigation in that field at the institution. All participants included in the study provided voluntary consent and possessed a comprehensive understanding of the study objectives and procedures. They were given the opportunity to address any questions or concerns they had before agreeing to participate. Moreover, participants were explicitly informed of their right to withdraw from the study at any point without negative consequences and were assured that the procedures involved would not result in any physical, psychological, or moral harm. Formal consent was obtained through the signing of an Informed Consent Form (Attachment II), adhering to the principles outlined in the 1964 Helsinki Declaration.

2.4 Instruments

2.4.1 Sample selection and characterization

Anthropometric measurements of body mass (kg) and height (m) were evaluated using the Tanita® BC-601 (Tanita- Body Composition Monitor®, Tokyo, Japan) scale with an accuracy of 0.1Kg, and a tape measure with an accuracy of 1mm.

To assess cognitive functions, the Mini-Mental State Examination (MMSE) was used (Santana et al., 2016). This evaluation encompasses seven cognitive domains, including visual construction, short-term memory, temporal orientation, spatial orientation, language, registration, and attention and calculation. For the Portuguese population, specific criteria were employed to identify cognitive deficits based on the MMSE scores. For illiterate participants, a final score of 15 or below indicates cognitive impairment. Individuals with a maximum of 11 years of schooling are considered to have a cognitive deficit if they score 22 or below. Lastly, participants with more than 11 years of education are classified as cognitively impaired if their final score is 27 or lower, as determined by Nunes et al., 2010. The Portuguese version of the MMSE was validated by Guerreiro in 1994, exhibiting a specificity ranging from 90% to 96% and a sensitivity between 63.6% and 73.4%, as reported by (Morgado, Rocha, Maruta, Guerreiro, &

Martins, 2009) (Attachment III).

2.4.2 Kinematic and kinetic analysis

For the acquisition of kinematic data, we resorted to the Qualisys® motion capture system (Qualisys AB, Gothenburg, Sweden), version 2020.3, with a frequency of 100Hz, consisting of 11 cameras. It was also be used the Qualisys Track Manager software (Qualisys AB, Gothenburg, Sweden) version 2.7, which allows synchronization with force platforms for data analysis. To extract the kinematic and spatiotemporal data from this software and for its subsequent analysis, we used the Fit to 2nd degree curve filter.

The ground reaction forces were collected through two force platforms (model FP4060-10 and FP4060-08; BERTEC, Columbus, OH, USA) that are connected to a signal amplifier (model AM6300; BERTEC) with a frequency of 100Hz. These platforms are 60 cm long and 40 cm wide and were embedded in the ground on a flat, rigid surface to minimize any vibrations (Sousa et al., 2012). The aforementioned platforms make it possible to measure the three components of the ground reaction forces through four sensors, which record them when applied in the anteroposterior (x), mediolateral (y) and vertical (z) directions and still detect the displacement of the Center of Pressure (CoP).

2.5 Procedures

2.5.1 Pilot study

Prior to the present study, a pilot study was carried out in order to test the methodology and procedures defined above. It was carried out with only one individual, who was not included in the data collection for the exploratory analysis.

2.5.2 Data collection protocol

The data collection process took place in a controlled environment at the Center for Research in Rehabilitation (CIR), of School of Health of the Polytechnic Institute of Porto.

Through the responses to the questionnaire via e-mail, the inclusion and exclusion criteria were applied and the participants were selected (Attachment IV). At the beginning, anthropometric data regarding weight and height were collected using a scale (Tanita® BC-601) and a tape measure, respectively.

Before performing the kinematic collection, the equipment was calibrated, in which the Qualisys® calibration value is accepted when the standard deviation of the measurements obtained is ≤ 0.5mm (Senior, 2004).

Prior to performing the task, the participants remain in the orthostatic position, with both feet on a force platform, for ten seconds.

Reflective markers were placed on the bone prominences designated in attachment V , according to Cappozzo, Catani, Della Croce, & Leardini, (1995).

2.5.3 Procedures for Performing the Functional Task

A brief explanation of all procedures was given to all individuals who participate in the study, who were also instructed to perform the functional tasks in shorts/top and usual footwear.

After an explanation regarding the procedures, the subjects were instructed to walk at a self-selected speed over a distance of 10 m, after the verbal command "begin", always given by the same investigator (Burnett et al., 2011; A. Silva et al., 2015; Sousa, Silva, & Santos, 2015). No additional guidelines were given regarding the limb with which individuals should start walking (Sousa et al., 2015).

Participants were set to perform three valid trials, with one trial being considered valid when a gait cycle was captured by both force platforms (Couto et al., 2023). In order to avoid fatigue, subjects had one minute to rest between each trial.

2.6 Data analysis

2.6.1 Gait

The gait cycle consists of two main phases: the stance phase and the swing phase. The stance phase accounts for approximately 60% of the gait cycle, with the swing phase comprising the remaining 40% (Elders, Greenwald, & Sartor, 1997; Laribi & Zeghloul, 2020; L. M. Silva & Stergiou, 2020).

This study focuses specifically on the initial contact and midstance subphases of the gait cycle. The initial contact phase marks the moment when the foot first touches the ground, resulting in a rapid increase in ground reaction forces as the foot absorbs the impact of landing. In the analysis, initial contact was defined as the point at which the vertical ground reaction force exceeded 5% of body weight (Vaverka, Elfmark, Svoboda, & Janura, 2015).

During the midstance phase, the ground reaction forces peak and primarily act in a vertical direction. In this subphase, the body's weight is supported by a single limb, and the foot remains stable while the body continues to move forward. The midstance period begins after the toe-off of the opposite foot and concludes with heel lift, representing the moment when both the forefoot and rearfoot are on the ground. Throughout midstance, vertical ground reaction forces reach approximately 75% of body weight, gradually increasing to slightly greater than body weight by the end of the subphase. Midstance encompasses approximately 26% of the full gait cycle (Kawalec, 2017)

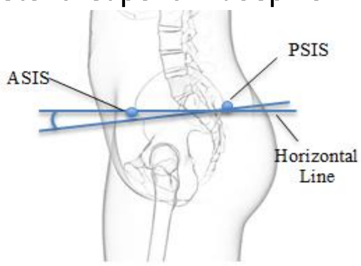
In order to reduce the error in determining the beginning of the initial contact, the body weight value was obtained through the vertical force (Fz) during the permanence on the force platform in the aforementioned orthostatic position.

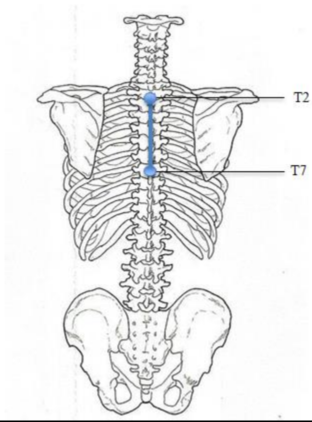
The kinematic variables are described in the following tables (table 1 and table 2):

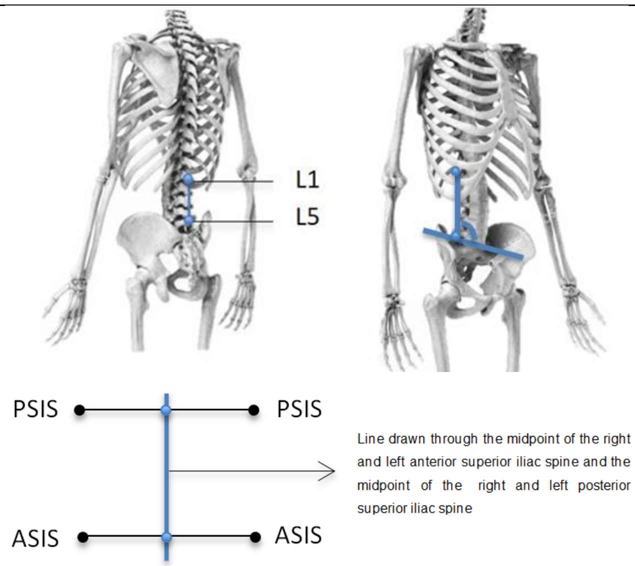
Table 1. Kinematic variables considered and used in this study

Kinematic Variables	● Pelvic Angle ● Distance between the spinous processes from T2 to T7 ● Lumbar Angle

Table 2. Description of the kinematic variables used

Variable (References)	Anatomical plane, anatomical references and respective movements under study
Pelvic Angle Adapted from (Oatis, 2009; Van Criekinge et al., 2017)	• **Sagittal plane:** <u>Anterior and posterior pelvic tilt</u>: angle between a line drawn through the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS) and the horizontal. **Anatomical references:** - Right anterior superior iliac spine: RASIS - Left anterior superior iliac spine: LASIS - Right posterior superior iliac spine: RPSIS - Left posterior superior iliac spine: LPSIS 
Distance between the spinous processes from T2 to T7	• **Sagittal plane:** <u>Flexion and extension of the upper trunk</u>: An increase in the distance (mm) between the 2 markers (more positive value)

Adapted from (Cappozzo et al., 1995) (Johnson, Cacciatore, Hamill, & Emmerik, 2010; Christe, Redhead; & Thomas, 2016)	defines the flexion of the upper trunk and a decrease in it (more negative value) defines the extension of this segment; **Anatomical references:** - T2 Thoracic vertebra: TV2 - T7 Thoracic vertebra: TV7 
Lumbar Angle Adapted from (Tully, Fotoohabadi, & Galea, 2005)	• **Sagittal plane:** <u>Flexion and extension of the lumbar:</u> angle between the line drawn through L1 and L5 and the line drawn through the midpoint of the right and left anterior superior iliac spine and the midpoint of the right and left posterior superior iliac spine. Values under 90° could suggest flexion. **Anatomical references:** - Right anterior superior iliac spine: RASIS - Left anterior superior iliac spine: LASIS - Right posterior superior iliac spine: RPSIS - Left posterior superior iliac spine: LPSIS - L1 lumbar vertebra: LV1 - L5 lumbar vertebra: LV5


L1
L5
PSIS
PSIS
Line drawn through the midpoint of the right and left anterior superior iliac spine and the midpoint of the right and left posterior superior iliac spine
ASIS
ASIS

2.7 Statistic Procedures

For the statistical analysis of the acquired data, the IBM Company (USA) Statistic Package Social Science (SPSS) software, version 29, was used, with a significance level of 0.05, with a confidence interval of 95%.

For inferential statistics, Mann-Whitney test and Wilcoxon test were used for an intergroup and within group analysis. Fisher exact test was used to compare the groups regarding the qualitative variables. The use of non-parametric tests was supported since the assumptions of the t-test (using the Shapiro-Wilk test) and the Chi-Squared test were not met.

Median and interquartile range were used as descriptive statistics for quantitative data and absolute and relative frequencies for the qualitative data.

3. Results

3.1 Sample Characterization

Table 3. Sample Characterization

	Post-Stroke		Healthy		p value
	Median	**(P_{25};P_{75})**	**Median**	**(P_{25};P_{75})**	
Age (years)	58,00	(46,75;65,00)	58,00	(45,00; 64,50)	0,982
Weight (Kg)	81,00	(77,25;89,23)	83,50	(77,50; 87,25)	0,664
Height (m)	1,75	(1,71;1,83)	1,76	(1,72; 1,81)	0,778
BMI (kg/m^2)	26,40	(23,83;29,50)	26,72	(25,05; 28,61)	0,901
Post-stroke time (years)	2,50	(2,00;6,50)	---		---
	n	%	n	%	
Sex					
Female	1	(12,5%)	1	(12,5%)	≈1,000
Male	7	(87,5%)	7	(87,5%)	

The two groups under analysis were considered similar regarding the sample characterization variables, as no significant differences were identified in age, weight, height, BMI, and sex ($p>0.05$). It is noteworthy that the group of individuals post-stroke a median time post-stroke of 2.5 years.

3.2 Pelvic Anterior Tilt Angle

Table 4. Pelvic Anterior Tilt during initial contact and midstance phases, along with the asymmetry and range of motion for both ipsilesional (post-stroke group)/dominant (healthy group) and contralesional (post-stroke group)/non-dominant (healthy group) limbs, with the median values (with interquartile ranges). Statistical significance is indicated by p-values (Mann Whitney test and Wilcoxon test).

	Post-Stroke		Healthy		p value
	Median	**($P_{25};P_{75}$)**	**Median**	**($P_{25};P_{75}$)**	
Pelvic Anterior Tilt angle (°)					
Initial – Initial Contact					
IPSI/DOM	14,54	(10,68;20,75)	4,88	(2,35;10,20)	**0,038***
CONTRA/NDOM	8,84	(1,52;15,67)	3,47	(1,58;14,33)	0,574
Asymmetry	8,47	(0,90;10,23)	0,59	(-0,74; 2,42)	**0,049***
Final -Midstance					
IPSI/DOM	15,99	(6,92;19,35)	6,51	(3,39; 12,24)	0,195
CONTRA/NDOM	12,83	(7,45;18,36)	6,90	(1,50; 15,73)	0,195
Asymmetry	0,04	(-3,50;3,20)	0,42	(-1,92; 2,28)	0,959
Range (Final – Initial)					
IPSI/DOM	-1,79	(-3,95;2,69)	2,25	(1,10; 2,51)	0,195
CONTRA/NDOM	6,20	(2,32;7,74)	2,70	(1,35; 3,42)	**0,049***

* Significative differences.

Regarding pelvic movement, it was observed that the post-stroke group exhibited significantly higher values of anterior tilt at initial contact of the ipsilesional limb compared to the healthy (p=0.038). When the contralesional limb was at the initial contact phase, no significant differences were observed between the groups, although there was a tendency for the post-stroke group to present higher values of anterior tilt compared to the healthy group. These differences were consistent with greater asymmetry between sides observed in the stroke group compared to the healthy group (p=0.049).

Regarding the range of motion between the initial and final positions, it was observed that when the contralesional limb of the post-stroke group was in support, exhibited significantly greater movement compared to the non-dominant side of the healthy group (p=0.049).

3.3 Lumbar Angle

Table 5. Lumbar Angle during initial contact and midstance phases, along with the asymmetry and range of motion for both ipsilesional (post-stroke group)/dominant (healthy group) and contralesional (post-stroke group)/non-dominant (healthy group), comparing post-stroke and healthy groups, with median values (with interquartile) ranges). Statistical significance is indicated by p-values (Mann Whitney test and Wilcoxon test).

	Post-Stroke		**Healthy**		**p value**
	Median	**(P_{25};P_{75})**	**Median**	**(P_{25};P_{75})**	
Lumbar Angle (°)					
Initial – Initial Contact					
IPSI/DOM	89,86	(74,34; 95,51)	85,83	(69,83; 100,99)	0,878
CONTRA/NDOM	85,44	(68,18; 91,01)	85,41	(71,58; 101,29)	0,442
Asymmetry	2,93	(2,06; 5,83)	-1,11	(-4,20; -0,23)	**<0,001***
Final - Midstance					
IPSI/DOM	87,15	(71,25; 95,55)	91,54	(75,19; 101,64)	0,382
CONTRA/NDOM	88,96	(76,26; 92,75)	90,21	(74,95; 101,39)	0,645
Asymmetry	-0,90	(-4,14; 0,49)	0,36	(-0,11; 1,46)	0,234
Range (Final – Initial)					
IPSI/DOM	-0,56	(-2,27; 0,50)	2,29	(0,65; 10,20)	**0,010***
CONTRA/NDOM	2,85	(1,56; 5,05)	1,28	(0,04; 4,33)	0,234

* Significative differences.

At initial contact, the stroke group exhibited significantly greater asymmetry between sides compared to the healthy group (p<0.001), resulting from a position closer to extension when the ipsilesional limb was at the specific phase of gait when compared to the contralesional limb.
When analyzing the range of motion between the initial and final positions, different behaviors were observed when comparing when the ipsilesional and contralesional limbs were at support. Specifically, median analysis showed a slight flexion movement when the ipsilesional limb was in contact with the floor, while when it came to the contralesional limb and to both sides of the healthy group exhibited extension movements. This analysis was consistent with the significant differences observed between groups when comparing the range of motion variations between when the ipsilesional limb of the post-stroke group and the dominant limb of the healthy group were in support (p=0.010). However, it is worth noting the low magnitude of lumbar movement changes during the analysis.

3.4 Distance between T2–T7

Table 6. Distance between T2 and T7 during initial contact and midstance phases, along with the asymmetry and range of motion for both ipsilesional (post-stroke group)/dominant (healthy group) and contralesional (post-stroke group)/non-dominant (healthy group), comparing post-stroke and healthy groups, with median values (with interquartile). Statistical significance is indicated by p-values (Mann Whitney test and Wilcoxon test).

	Post-Stroke		**Healthy**		**p value**
	Median	**(P_{25};P_{75})**	**Median**	**(P_{25};P_{75})**	
Distance between T2-T7(mm)					
Initial – Initial Contact					
IPSI/DOM	189,69	(152,09;202,22)	180,01	(159,22;198,30)	≈1,000
CONTRA/NDOM	188,09	(162,38;201,45)	180,46	(159,11;198,62)	0,574
Asymmetry	-2,87	(-8,02;0,77)	-0,08	(-0,95;0,95)	0,161
Final - Midstance					
IPSI/DOM	184,61	(155,85;200,96)	180,38	(157,85;197,17)	0,798
CONTRA/NDOM	189,45	(156,05;202,00)	180,81	(158,39;197,55)	0,878
Asymmetry	1,12	(-4,22;2,88)	-0,53	(-0,83;-0,09)	0,382
Range (Final – Initial)					
IPSI/DOM	1,04	(-2,16;3,89)	-0,70	(-2,19;0,67)	0,442
CONTRA/NDOM	-1,81	(-6,83;0,60)	-0,23	(-1,06;0,48)	**0,043***

* Significative differences.

Similar to the lumbar spine, no significant differences were observed between the groups in either the initial or final positions (p>0.05). When analyzing the contralesional/non-dominant, although the range of motion (final – initial) was significantly greater in the stroke group compared to the healthy group (p=0.043), the magnitude of these differences appears to be small (median differences of approximately 2mm).

4. Discussion

The purpose of this study was to analyze the superior and inferior trunk and pelvic movements in the sagittal plane during the initial contact to the midstance phase of the gait cycle in post-stroke individuals and compare them to the ipsilesional and contralesional sides of the dominant and non-dominant limbs in healthy individuals. Furthermore, the study aimed to ascertain whether any asymmetries or disparities existed within the post-stroke group and within the healthy group during the aforementioned phases.

Pelvic Angles

Regarding anterior pelvic tilt, it was predicted that both groups would demonstrate some amount of anterior pelvic tilt at the beginning of the gait cycle. This tilt was expected to be maintained or increase throughout the gait cycle, as typical pelvic motion supported by the literature (Chen et al., 2003; In et al., 2021; Lewis, Laudicina, Khuu, & Loverro, 2017; Van Criekinge et al., 2017). This anticipation was further confirmed by the results of this study which revealed a trend of anterior pelvic tilt in both post-stroke and healthy groups from the initial contact to the end of the midstance phase which supports other studies. The outcomes notably demonstrated significantly higher anterior pelvic tilt values when the ipsilesional limb of the post-stroke group was at the initial contact of gait compared to the dominant side of the healthy group. Furthermore, a trend toward elevated anterior pelvic tilt values at midstance was observed within the post-stroke group, although no statistically significant disparities were noted between the two groups. This observation is consistent with documented postural alterations following a stroke, which often include excessive anterior pelvic tilt in the standing position (Suruliraj Karthikbabu et al., 2017; Van Criekinge et al., 2017). Given the expected impaired muscular control of the lower trunk in post-stroke individuals, which can be related to poor abdominal muscle activity, compromising trunk PC and leading to inadequate support for the lower trunk, it was anticipated that individuals in this group would exhibit higher anterior pelvic tilt angles, potentially resulting in compensatory strategies involving the pelvic segment (Cabanas-Valdés et al., 2021; Karatas et al., 2004; Suruliraj Karthikbabu et al., 2017; Verheyden et al., 2014, 2006).

In addition, the results revealed a higher level of contralesional/ipsilesional asymmetry during initial contact in the stroke group compared to the healthy group. In particular, the anterior pelvic tilt values were significantly higher when the ipsilesional limb was at the initial contact than when the contralesional limb was at the same phase of the gait cycle. This can be explained by the differences in postural orientation, stability, and muscle activation between the two sides described in the literature (Aze et al., 2016; Dai, Suresh, Suresh, Rymer, & Hu, 2017; Fujita, Kobayashi, & Hitosugi, 2021; Hadjiosif et al., 2022; Jones, 2020). These alterations demonstrate the interaction between the lower limbs and trunk movements during walking, underlining the significance of adequate coordination of the lower limbs in maintaining stability during this complex task (Ekmekcioglu, Katirci Kirmaci, & Ergun, 2023; Little et al., 2018). Post-stroke individuals often experience deficits in interlimb coordination and thus, alterations in the lower limb and trunk movement patterns (Couto et al., 2023; Sousa, Silva, Santos, Sousa, & Tavares, 2013). The reticulospinal tract is essential for interlimb coordination, and is commonly affected after a stroke, leading to bilateral changes in trunk and lower limb muscle control and postural orientation (Guggisberg et al., 2019; Jang & Lee, 2019; Little et al., 2018; Tamaya et al., 2020). These disruptions may manifest as asymmetries in gait, affecting both the ipsilesional and contralesional sides differently (Jang et al., 2013; A. Silva et al., 2017). This can lead to changes in coordination and stability and changes in the postural orientation of the pelvis and trunk and lead to deviations such as anterior pelvic tilt (Ivanenko & Gurfinkel, 2018; Little et al., 2018; Van Criekinge et al., 2017). It should be noted that due to the involvement of the pontine reticulospinal tract, which is disposed mainly ipsilaterally, these impairments could predominantly affect the ipsilesional side, possibly explaining why the anterior pelvic tilt values were higher when the ipsilesional limb was at the initial contact compared to when the contralesional limb was at the same phase of gait (Baker, 2011; Jang et al., 2013; Jang & Lee, 2019; Karatas et al., 2004; Lefebvre & Liew, 2017; A. Silva et al., 2013; Westlake & Nagarajan, 2011).

Conversely, the results also indicated that, despite of the higher anterior pelvic tilt values observed when the ipsilesional limb was at initial contact compared to the contralesional limb, the pelvis exhibited a greater range of motion when the contralesional limb of the post-stroke group moved from the initial contact to midstance. The greater variation in pelvic motion when the contralesional limb was in these specific phases of gait could likely be due to different compensatory and movement strategies that could result from limitations in hip flexion, knee flexion, and dorsiflexion (Balaban & Tok, 2014; Van Criekinge et al., 2017). Such compensatory strategies can lead to altered motor patterns in the contralesional limb, influencing pelvic movement and potentially increasing its range of motion (Balaban & Tok, 2014; Couto et al., 2023; Do Carmo, Kleiner, & Barros, 2015; Karatas et al., 2004; Sousa et al., 2015, 2013; Van Criekinge et al., 2017).

Lumbar Angles

When examining the lumbar angle, there was no difference between the groups in the initial position and the final position. However, when examining lumbar motion during the initial contact phase of the ipsilesional limb, the lumbar tends to start closer to extension compared to the contralesional side, revealing significantly greater asymmetry between sides compared to healthy individuals. This finding is consistent with the results on the pelvic tilt, where the pelvis starts with a greater anterior tilt when the ipsilesional limb is in the initial contact, indicating more lumbar lordosis, which is typical for post-stroke patients in the standing position (Chen et al., 2003; In et al., 2021; Król, Polak, Szczygieł, Wójcik, & Gleb, 2017; Lewis et al., 2017; Van Criekinge et al., 2017).

Indeed, there is a notable difference in the range of motion of the lumbar angle. Median values indicate a slight tendency towards flexion when the ipsilesional limb moves from initial contact to the end of midstance, while the contralesional limb and both sides of the healthy group exhibit a tendency towards extension movements during the same phases of gait. This could be because the ipsilesional side starts with higher lumbar extension at initial contact, possibly allowing for less variation. Additionally, during these specific gait phases, the contralesional side shows greater postural variation in the lumbar region, whereas the ipsilesional side exhibits less variation, likely due to impairments in the reticulospinal tract, which compromise the postural orientation, as mentioned before (Baker, 2011; Guggisberg et al., 2019; Jang et al., 2013; Jang & Lee, 2019; Sousa et al., 2013). It is important to note that the overall magnitude of lumbar movement values is low during the analysis, as literature indicates that the pelvis and lower trunk move minimally during gait (In et al., 2021; Lewis et al., 2017).

Trunk Segment Distance

When comparing the distance between T2 and T7, as in the lumbar spine, no significant differences were noted between the post-stroke and the healthy groups in either the initial or final positions. This could suggest that there is minimal movement of this segment in the sagittal plane. This limited range of motion could be partly explained by the fact that during this particular task, there is a need to maintain trunk stability, as this task requires a high level of stability and control (Titus, Hillier, Louw, & Inglis-Jassiem, 2018; Van Criekinge et al., 2017; Winter, Ruder, & MacKinnon, 1990). Further, the distance between T2 and T7 may vary for different people due to differences in body structure and height, which may decrease the focus on this measure. These structural variations could explain the lack of motion seen in this segment and thus it is important to consider individual structural variations that may affect these measurements, which in turn may explain the observed minimal motion in the sagittal plane.

Regarding the assessment of the distance between T2 and T7 at the initial contact to midstance phase of gait for both the contralesional and non-dominant, the range of motion was found to be different between the post-stroke and healthy groups. More precisely, the post-stroke group demonstrated a slight wider range of motion in terms of the distance between T2 and T7 when the contralesional limb was in support. However, the degree of these differences was not large, and the median differences were close to 2mm. This is a minor difference which may not be clinically relevant, given the inherent variability in trunk measurements and the small sample size. In general, although the present study demonstrated that there were minor changes in trunk movement in post-stroke patients, the implications of these results need to be explored further and confirmed in future research with a higher number of participants and more extensive assessment tools.

Study Limitations

Firstly, the number of participants in the study may be insufficient to generalize the results to a wider population as a larger sample would allow for a more comprehensive analysis and might highlight other differences in postural orientation. Secondly, the study used linear measures to determine postural orientation, and this may not capture the complexity of postural control dynamics. Further research should use nonlinear indices to capture the dynamics and variability of postural control in post-stroke individuals. Additionally, the use of markers for postural orientation may not be the most accurate because of the errors that may be induced by the placement of these markers and may not fully represent the underlying biomechanical changes. Future research should use nonlinear measures and more precise tracking methods to provide deeper insights into postural dynamics and enhance rehabilitation strategies for post-stroke individuals. These improvements could help to offer a better understanding of the processes that underlie postural control and may be useful for improving the rehabilitation process and contribute to more effective rehabilitation strategies. Nevertheless, it is important to highlight that assembling a homogeneous sample in the post-stroke population and even among healthy individuals poses a major challenge due to the considerable variability in movement and heterogeneity within each individual.

5. Conclusion

This study revealed that post-stroke individuals exhibit greater anterior pelvic tilt at initial contact when the ipsilesional limb was in support compared to healthy individuals. Additionally, post-stroke individuals showed a greater range of pelvic motion when the contalesional limb was in support during the initial contact to the midstance phase of gait. While no significant differences were found in the lumbar angles between groups, greater asymmetry was observed in the post-stroke group at the initial contact. The distance between T2 and T7 showed greater range of motion when the contralesional limb was in support compared to the non-dominant limb, although the magnitude of these values was small.

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Attachments

I. Ethics Committee Approval

P.PORTO

ESCOLA
SUPERIOR
DE SAÚDE
POLITÉCNICO
DO PORTO

PARECER DA COMISSÃO DE ÉTICA

Número de Registo da Comissão de Ética: CE0054D
Data receção do Documento: 17/11/2023
Existência de entradas anteriores: Sim (25/10/2023 e 02/05/2023)

TÍTULO DO TRABALHO: NEUROBIOMECHANICS CHARACTERIZATION OF STROKE

INVESTIGADOR RESPONSÁVEL: MARTA GONÇALVES

DATA PREVISTA PARA A REALIZAÇÃO DO TRABALHO: Início 28/11/2023 | Fim 30/12/2026

RESUMO DO ESTUDO

OBJETIVOS: Nada a referir.

AMOSTRA: A indicação dos indivíduos, por parte dos responsáveis das entidades, só será realizada, caso o participante concorde previamente em colaborar no estudo e qualquer dado só será registado após assinatura do consentimento informado. Para a amostra de indivíduos saudáveis, quer para o estudo em si quer para o estudo piloto, só será usado o email institucional via secretariado da presidência, contacto presencial ou redes sociais. Os investigadores usarão apenas comunidade da ESS.

FORMULÁRIO DE DADOS A RECOLHER: Questionário apresentado em formato papel e digital, corrigido. Esclarecido que será aplicado a todos os participantes saudáveis e do estudo piloto. Relembra-se que as respostas de participantes com fatores de exclusão deverão ser imediatamente eliminadas do registo.

MATERIAL: Nada a referir.

MÉTODOS: O cronograma foi novamente ajustado. Os dados vão ser armazenados no computador do investigador principal e apenas acessível com password. Dados vão ser destruídos após o término temporal previsto da realização do estudo – entende-se desta frase que seja logo após o fim do projeto. Salienta-se a necessidade de a base de dados ser encriptada.

RISCOS: Refere que são inexistentes.

CONSENTIMENTO INFORMADO: Corrigido.

AUTORIZAÇÃO PELOS RESPONSÁVEIS LOCAIS: MO.313 conforme. Sendo um doutoramento da FADEUP e tendo esta instituição protocolo com a ESS|Porto não existe necessidade de autorização do departamento da instituição, tal como confirmado via email pelo coordenador do Programa Doutoral em Fisioterapia Professor Jorge Mota. Foi esclarecido que a recolha da amostra não será em diferente UO do P.Porto, mas sim apenas na EES, por isso não existe a necessidade de apresentar essas declarações/autorizações das UO.

APRECIAÇÃO DA COMISSÃO DE ÉTICA: As dúvidas levantadas foram esclarecidas e os documentos retificados. Salienta-se apenas o cumprimento do exposto infra e nos documentos anteriores.

PARECER FINAL DA COMISSÃO DE ÉTICA: De acordo com os dados analisados, o parecer é favorável desde que cumpridas todas as diretrizes submetidas a esta Comissão, recomendando-se que a decisão seja suspensa caso haja algum incumprimento grave.

24/11/2023

Assinado por: **Pedro Manuel Ribeiro da Rocha Monteiro**
Num. de Identificação: 09132856
Data: 2023.11.24 15:41:41 +0000

SGS ESS.004 MO.318.02

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II. Informed Consent Form

P.PORTO

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DO PORTO

TERMO DE
CONSENTIMENTO INFORMADO

<u>DESIGNAÇÃO DO ESTUDO</u>: "*Neurobiomechanics Characterization of* Stroke"

Declaração de Consentimento Informado

Eu,abaixo-assinado
(____
________________________)
Fui informado de que o Estudo de Investigação, acima mencionado, se destina a um projeto de investigação que visa a caracterização das variáveis biomecânicas com impacto no desempenho das atividades funcionais, em indivíduos pós-AVC.
Sei que neste estudo está prevista a realização de uma avaliação clínica e recolha de dados durantes as tarefas: posição de sentado, passagem de sentado para de pé, passagem de pé para sentado, posição de pé, marcha e subir um degrau. As medidas antropométricas massa corporal (Kg) e altura (m) serão avaliadas através de uma balança Tanita® BC-601 (Tanita – Body Composition Monitor®, Tokyo, Japão) e uma análise cinemática através do sistema optoelétrico Qualisys Motion Capture System.
Foi-me garantido que todos os dados relativos à identificação dos Participantes neste estudo são confidenciais e que será mantido o anonimato.
Sei que posso recusar-me a participar ou interromper a qualquer momento a participação no estudo, sem nenhum tipo de penalização por este facto.
Compreendi a informação que me foi dada, tive oportunidade de fazer perguntas e as minhas dúvidas foram esclarecidas.
Aceito participar de livre vontade no estudo acima mencionado.
Também autorizo a divulgação dos resultados obtidos no meio científico, garantindo o anonimato.

Nome do Investigador e Contacto: Marta Freitas (916143447)

Data e Assinatura Participante:

____/_____/________,____

SGS ESS.0004.MO.317.02

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III. Mini Mental State Examination (MMSE)

<u>Mini Mental State Examination (MMSE)</u>

1. **Orientação** (1 ponto por cada resposta correta)

Em que ano estamos? ________ Em que mês estamos? _____

Em que dia do mês estamos? _____

Em que dia da semana estamos? ________ Em que estação do ano estamos? ___________ **Nota**:______

Em que país estamos? ________ Em que distrito vive? _____________________ Em que terra vive? ____________________

Em que casa estamos? ________ Em que andar estamos? ____________________ **Nota**:______

2. **Retenção** (contar 1 ponto por cada palavra corretamente repetida)

"Vou dizer três palavras; queria que as repetisse, mas só depois de eu as dizer todas; procure ficar a sabê-las de cor".

Pêra

Gato

Bola

Nota:____

3. **Atenção e Cálculo** (1 ponto por cada resposta correta. Se der uma errada mas depois continuar a subtrair bem, consideram-se as seguintes como corretas. Parar ao fim de 5 respostas)

"Agora peco-lhe que me diga quantos são 30 menos 3 e depois ao número encontrado voltaa tirar 3 e repete assim até eu lhe dizer para parar".

27_ 24_ 21 _ 18_ 15_

Nota:____

4. **Evocação** (1 ponto por cada resposta correta.)
5.

"Veja se consegue dizer as três palavras que pedi há pouco para decorar".Pêra ______
Gato__________ Bola _

Nota:____

6. **Linguagem** (1 ponto por cada resposta correta)

a. "Como se chama isto? Mostrar os objetos:

Relógio ________
Lápis__________ **Nota**:________

b. "Repita a frase que eu vou dizer: O RATO ROEU A ROLHA"

Nota:___

c. "Quando eu lhe der esta folha de papel, pegue nela com a mão dominante, dobre-a ao meio e ponha sobre a mesa"; dar a folha segurando com as duas mãos.
Pega com a mão dominante___ Dobra ao meio ______
Coloca onde deve________

Nota:____

d. Leia o que está neste cartão e faça o que lá diz". Mostrar um cartão com a frase bemlegível, "FECHE OS OLHOS"; sendo analfabeto lê-se a frase.
Fechou os olhos________

Nota:____

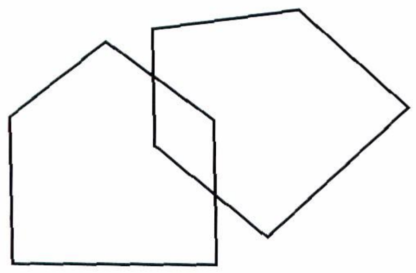
e. "Escreva uma frase inteira aqui". Deve ter sujeito e verbo e fazer sentido; os errosgramaticais não prejudicam a pontuação.

Frase:

Nota:____

7. **Habilidade Construtiva** (1 ponto pela cópia correta.)

Deve copiar um desenho. Dois pentágonos parcialmente sobrepostos; cada um deve ficar



com 5 lados, dois dos quais intersectados. Não valorizar tremor ou rotação.

Cópia:

Nota:

TOTAL(Máximo 30 pontos):

<u>**Considera-se com defeito cognitivo**</u>:

- analfabetos ≤ 15 pontos
- 1 a 11 anos de escolaridade ≤ 22
- com escolaridade superior a 11 anos ≤ 27

IV. Questionnaire for Characterization of Post-Stroke Individuals

P.PORTO ESCOLA SUPERIOR DE SAÚDE

Questionário Caracterização Participantes

Este questionário foi realizado no âmbito do projeto de investigação "*NeuroBiomechanics Caracherization of Stroke*" da Escola Superior de Saúde do Instituto Politécnico do Porto sob a orientação da Professora Doutora Augusta Silva, Professor Francisco Pinho e Professor João Paulo Vilas Boas.

É um questionário de preenchimento rápido com a garantia da máxima confidencialidade no tratamento dos dados recolhidos, bem como o uso exclusivo dos mesmos apenas para efeitos deste estudo.

Agradeço a colaboração pedindo que responda de forma sincera e estou disponível para qualquer esclarecimento adicional.

1. Idade: ___(anos)

2. Sexo: Masculino ☐ Feminino ☐

3.Grau Escolaridade:________(anos)

4.Profissão:____________

5. História Médica:

- Fatores de risco vasculares: doença arterial coronariana ☐ diabetes ☐ hipertensão ☐ obesidade clínica ☐ tabagismo ☐ e uso de álcool ☐ hiperlipidemia/dislipidemia ☐
- Insuficiência renal ou cardíaca ☐
- AVC prévio ou ataque isquémico transitório (AIT) ☐ Data:______
- Condições co-mórbidas: declínio cognitivo (MMSE) ☐ osteoartrite ☐ outra doença neurológica ☐

6. Data AVC:____/____/____ Isquémico ☐ Hemorrágico ☐

- Subtipo de AVC: Lacunar ☐ Grande artéria ☐ Outro ☐ Qual?___________

7. Localização do AVC:

- Cortical: Cápsula Interna ☐ Artéria Cerebral Média (MCA) ☐ Lobo Frontal ☐
- Subcortical: Tálamo ☐ Gânglios da Base ☐
- Mesencéfalo: Ponte ☐ Medula ☐ Cerebelo ☐
- Tronco cerebral ☐
- Sem informação ☐

7. Tempo de internamento:_____(dias)

7. Marcha pós-AVC:

- Independente com auxiliar de marcha ☐
- Independente com ou sem auxiliar de marcha ☐
- Com assistência ☐
- Incapaz ☐

8. Gravidade do AVC: Escala do Instituto Nacional de Saúde (NIHSS)_______

12. Trombólise/terapia de reperfusão: Sim ☐ Não ☐

13. Tem algum défice visual? Sim ☐ Não ☐

Se sim, usa algum tipo de correção (por exemplo óculos)? ___________________________

14. Faz medicação? Sim ☐ Não ☐

Se sim, usa algum tipo de correção (por exemplo óculos)?___________________________

15. Outras observações:

Mão dominante (com que mão escreve? Mão dominante ☐ Mão não-dominante

V. Positioning of reflective markers in the respective anatomical landmarks

Upper limb		
Name	Side	Localization
RALH	Right	Anterolateral portion of the head
LALH	Left	
RPLH	Right	Posterolateral portion of the head
LPLH	Left	
REAR	Right	Earlobe
LEAR	Left	
RACJ	Right	Acromion
LACJ	Left	
C7	-	C7 cervical vertebra
TV2	-	T2 Thoracic vertebra
TV7	-	T7 Thoracic vertebra
LV1	-	L1 Lumbar vertebra
LV3	-	L3 Lumbar vertebra
LV5	-	L5 Lumbar vertebra
SJN	-	Jugular notch
SXS	-	Xiphoid Process
RLELB	Right	Lateral Epicondyle of Humerus
LLELB	Left	
RMELB	Right	Medial Epicondyle of Humerus
LMELB	Left	
RFA	Right	Forearm (tracking)
LFA	Left	
RRAD	Right	Radial Styloid Process
LRAD	Left	
RULN	Right	Cubital Styloid Process
LULN	Left	
RLH	Right	Medial Aspect of the Head of the 2nd Metacarpal

LLH	Left	Medial Aspect of the Head of the 2nd Metacarpal
RMH	Right	Medial Aspect of the Head of the 5th Metacarpal
LMH	Left	
Lower Limb		
RIAS	Right	Antero Superior Iliac Spine
LIAS	Left	
RIPS	Right	Postero Superior Iliac Spine
LIPS	Left	
RFTC	Right	Greater Trochanter of the Femur
LFTC	Left	
LFLE	Right	Lateral Epicondyle of the Femur
RFLE	Left	
RFME	Right	Medial Epicondyle of the Femur
LFME	Left	
RFAX	Right	Fibula's head
LFAX	Left	
RTTC	Right	Anterior tuberosity of tibia
LTTC	Left	
RFAL	Right	Lateral Malleolus
LFAL	Left	
RTAM	Right	Medial Malleolus
LTAM	Left	
RFCC	Right	Posterior aspect of the Calcaneus
LFCC	Left	
RFM1	Right	Dorsal Aspect of the 1st Metatarsal Head
LFM1	Left	
RFM2	Right	Dorsal Aspect of the 2nd Metatarsal Head
LFM2	Left	
RFM5	Right	Dorsal Aspect of the 5th Metatarsal Head
LFM5	Left	
Clusters		

RUA1 RUA2 RUA3	Right	Forearm Upper Limb
LUA1 LUA2 LUA3	Left	
RTH1 RTH2 RTH3 RTH4	Right	Lower Limb Thigh
LTH1 LTH2 LTH3 LTH4	Left	
RSK1 RSK2 RSK3 RSK4	Right	Lower Limb Leg
LSK1 LSK2 LSK3	Left	